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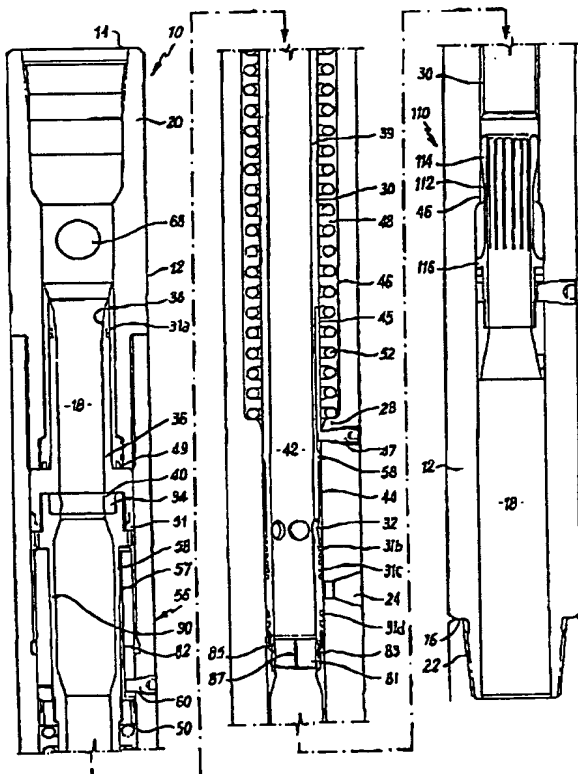
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(54) Title: DOWNHOLE TOOL



(57) Abstract: A downhole tool which can perform a task in a well bore, such as circulating fluid radially from the tool. The function is selectively performed by virtue of a sleeve moving within a central bore of the tool. Movement of the sleeve is effected by dropping a ball through a ball seat on the sleeve. Movement of the sleeve is controlled by an index sleeve such that the tool can be cycled back to the first operating position by dropping identical balls through the sleeve. Embodiments are described wherein the balls are deformable, the seat is deformable and the seat provides a helical channel through which the ball passes.

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1 Downhole Tool

2

3 The present invention relates to the selective operation
4 of downhole tools as used in the oil and gas industry and
5 in particular, though not exclusively, to a re-settable
6 circulation tool operated by a drop ball mechanism.

7

8 While many downhole tools operate continuously through a
9 well bore e.g. scrapers and brushes as disclosed in US
10 6,227,291, it is more desirable to provide a tool which
11 performs a function only when it has reached a preferred
12 location within a well bore. An example of such a tool
13 would be a circulation tool as disclosed in WO 02/061236.
14 The tool provides a cleaning action on the walls of the
15 casing or lining of the well bore. The cleaning action
16 may be required after the casing has been brushed or
17 scraped and thus the tool is designed to be selectively
18 actuated in the well bore. Such tools provide the
19 advantage of allowing an operator to mount a number of
20 tools on a single work string and operate them
21 individually on a single trip in to the well bore. This
22 saves significant time in making the well operational.

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1 Tools which are selectively actuatable in a well bore
2 commonly operate by having an element which can be moved
3 relative to the tool when in the well bore. In the
4 circulation tool of WO 02/061236, the element is a sleeve
5 located in the cylindrical body of the tool. When run in
6 the well, the sleeve is held in a first position by one
7 or more shear screws. To actuate the tool, a drop ball
8 is released from the surface of the well through the work
9 string. On reaching the sleeve, the ball blocks the flow
10 of fluid through the tool and consequently pressure
11 builds up until the shear screws shear and the sleeve is
12 forced downwards. The movement of the sleeve is then
13 stopped when a lower ledge of the sleeve contacts a
14 shoulder on the internal surface of the tool body.

15
16 Such tools have a number of disadvantages. The tools are
17 generally limited to one actuatable movement. If two
18 sleeves are incorporated to overcome this, the shear
19 screws of the second sleeve can operate prematurely under
20 the shock created to shear the shear screws of the first
21 sleeve. Additionally, the reduced bore diameter of the
22 lower part also effects the flow rate achievable through
23 the tool.

24
25 One tool which has been developed to operate repeatedly
26 is that disclosed in US 4,889,199. This tool comprises a
27 tubular body having a radial port into which is located a
28 sleeve having a matching radial port. The sleeve is
29 slidably mounted and its action controlled from a
30 deformable drop ball biasing the sleeve against a spring.
31 Initially the spring biases the sleeve to a closed
32 position in which the ports are misaligned. The drop ball
33 causes the sleeve to move to a position where the ports

1 align due to a build up of pressure behind the ball, and
2 fluid is discharged radially through the ports. A small
3 steel ball is then dropped into the tool which seals the
4 radial ports and the consequential pressure build up
5 extrudes the deformable ball through the ball seat. The
6 steel ball will drop with the deformable ball and both
7 are retained in a ball catcher at the base of the tool.
8 When the balls drop together the spring biases the sleeve
9 back to the closed position and the tool can be operated
10 repeatedly.

11

12 A disadvantage of this tool is that it requires both a
13 deformable ball and a smaller metal ball to operate. Care
14 must then be taken to ensure the balls are dropped in the
15 correct order. The smaller metal ball must lodge in the
16 second, radial, outlet in order to stop flow and thus the
17 tool is restricted to having a single radial port. This
18 limits the amount of cleaning which can be performed.

19

20 It is an object of the present invention to provide a
21 downhole tool which obviates or mitigates at least some
22 of the disadvantages of the prior art.

23

24 It is a further object of at least one embodiment of the
25 present invention to provide a circulation tool which is
26 re-settable and operated by similar drop balls.

27

28 It is a further object of at least one embodiment of the
29 present invention to provide an actuation mechanism to
30 move a sleeve within a downhole tool.

31

32 According to a first aspect of the present invention
33 there is provided a downhole tool for selectively

1 performing a task in a well bore, the tool comprising a
2 substantially cylindrical body having a central bore
3 running axially therethrough, a sleeve located within the
4 bore, the sleeve including a ball seat, a plurality of
5 balls, each ball having substantially similar dimensions
6 and each ball arresting a majority of fluid flow through
7 the bore when located in the ball seat, mechanical
8 biasing means located between the sleeve and the body to
9 bias the sleeve in a first direction, and functional
10 means on the body to perform a task in the well bore, the
11 functional means being operable on relative movement of
12 the sleeve, wherein the functional means has at least a
13 first and a second operating position, each change in
14 position being effected by passing a said ball through
15 the sleeve in a reverse direction, and wherein the said
16 changes form a cyclic pattern such that the functional
17 means can be cycled back to the first operating position.

18

19 The tool can therefore be operated a number of times
20 while located in a well bore. Further all operations are
21 controlled by dropping identical balls through the tool
22 and thus there is no co-ordination required in dropping
23 the balls.

24

25 It will be appreciated that while the term ball has been
26 used, this represents any shaped projectile which can be
27 dropped into the fluid flow, travel to and seat in the
28 ball seat, and further travel through the ball seat. Such
29 projectiles may be plugs, bombs darts or the like.

30

31 Preferably the ball seat releasably retains each ball.
32 Preferably the ball seat is a ledge or shoulder located
33 on an inner surface of the sleeve means. The ball

1 therefore rests on the shoulder until sufficient pressure
2 builds up to force the ball past the shoulder.

3

4 In a first embodiment, the balls are deformable. In this
5 way each ball can be released by passing through the ball
6 seat when sufficient pressure is applied to it.

7

8 When a ball is dropped in the body, the ball will locate
9 in the ball seat. The ball will block the fluid path
10 through the tool and consequently pressure will build up
11 on the ball by fluid prevented from travelling through
12 the body. This pressure will be sufficient to move the
13 ball and sleeve together against the mechanical bias and
14 force the sleeve in the reverse direction. When the limit
15 of the bias is reached, increased pressure will cause the
16 ball to deform and pass through the ball seat. On release
17 of the ball, pressure drops and the sleeve is biased in
18 the first direction. The movement of the sleeve actuates
19 the tool and moves the functional means to an operating
20 position.

21

22 In a second embodiment, the ball seat may be a deformable
23 ball seat. Preferably the deformable ball seat includes a
24 part conical surface having an aperture therethrough.

25 Advantageously the aperture has a diameter less than a
26 diameter of the ball. Preferably the deformable ball seat
27 is made of a flexible material, so that at a
28 predetermined pressure it flexes to release the ball.

29 Advantageously the deformable ball seat is made of a
30 metal so that the seat is not prone to wear during use.

31

32 The deformable ball seat may comprise a spring such as a
33 disc spring. Preferably the deformable ball seat has

1 sufficient elasticity such that it returns to its
2 original dimensions once a ball has passed therethrough.
3 Optionally the deformable ball seat may be of a layered
4 structure. Preferably the layered structure comprises a
5 plurality of disc springs.

6
7 Throughout this specification the term deformable refers
8 to the ability of an element to change shape within its
9 own volume as it deforms. This is in contrast to
10 expandable wherein the element must get bigger i.e.
11 extend beyond its outer diameter.

12
13 Preferably the balls of the second embodiment are
14 spherical. More preferably the balls are of a non-pliable
15 material and thus cannot deform. Advantageously the balls
16 are made of steel.

17
18 In the second embodiment, when a ball is dropped in the
19 body, the ball will locate in the deformable ball seat.
20 The ball will block the fluid path through the tool and
21 consequently pressure will build up on the ball by fluid
22 being impeded in travelling through the body. This
23 pressure will be sufficient to move the ball and sleeve
24 together against the mechanical bias and force the sleeve
25 in the reverse direction. When the limit of the bias is
26 reached, increased pressure will cause the seat to expand
27 against the pressure of the ball. The ball will pass
28 through the expanded ball seat. On release of the ball,
29 pressure drops and the sleeve is biased in the first
30 direction. The movement of the sleeve actuates the tool
31 and moves the functional means to an operating position.

32

1 In a third embodiment the ball seat may comprise a
2 helical channel on an inner surface of the sleeve.

3
4 Preferably the helical channel has curved walls. This
5 will prevent damage to a ball passing through the
6 channel. Preferably also the ball is sized to provide a
7 restricted fluid by-pass around the ball when in the
8 channel. This ensures a positive pressure is maintained
9 behind the ball and prevents chattering of the ball in
10 the channel.

11
12 The helical channel may be considered as a screw thread.
13 Thus the channel has a left hand thread so that a ball
14 travels in the opposite direction to the rotation of the
15 tool on a work string. Preferably a pitch of the thread
16 is greater than or equal to a diameter of each ball.

17
18 Preferably the balls are spherical. More preferably the
19 balls are of a non-pliable material and thus cannot
20 deform. Advantageously the balls are made of steel.

21
22 Preferably also the sleeve includes a conical surface at
23 an entrance to the channel. This funnels the ball into
24 the channel and ensures it travels into the helical path.

25
26 For this embodiment, when a ball is dropped in the body,
27 fluid will drive the ball into the channel and into the
28 helical path. As the ball is sized for the channel it
29 will block the majority of the fluid path through the
30 tool and consequently pressure will build up behind the
31 ball. This pressure will be sufficient to move the ball
32 and sleeve together against the spring and force the
33 sleeve in the reverse direction. On release of the ball

1 from the channel the sleeve is biased in the first
2 direction. The movement of the sleeve actuates the tool
3 and moves the functional means to an operating position.

4
5 Preferably the mechanical biasing means is a strong
6 spring. The spring may be helical, conical or the like. A
7 strong spring will prevent the sleeve moving in the
8 reverse direction by fluid flow in the central bore.
9 Preferably also the mechanical biasing means is located
10 in a chamber created between the sleeve and the body.
11 Advantageously the chamber includes an exhaust port such
12 that fluid can enter and be dispelled from the chamber by
13 relative movement of the sleeve and the body. This
14 provides a damping effect which prevents shock movements
15 in the tool.

16
17 Preferably a choke ring is located around the sleeve.
18 Preferably the ring has an extended portion in the
19 longitudinal plane to provide an extended surface area to
20 match the outer surface of the sleeve for fluid to flow
21 therebetween. The shape of the ring, assists in
22 providing a damping action as the sleeve moves in the
23 reverse direction. Fluid which has to pass the sleeve as
24 it moves downwards is forced to take a route having a
25 restricted flow path in the first direction. This
26 damping helps prevent the mechanical bias e.g. a spring
27 or other parts, from 'bouncing' into a location which
28 could result in the functional means being moved to an
29 unwanted operating position.

30
31 Preferably the tool further comprises engagement means to
32 control relative movement between the sleeve and the

1 body. Preferably also the mechanical bias biases the
2 sleeve against the engagement means.

3
4 Preferably said engagement means comprises at least one
5 index pin located in a profiled groove. Preferably the at
6 least one index pin is located on the body and the
7 profiled groove is located on an outer surface of the
8 sleeve. In this way, an index sleeve is produced with the
9 groove determining the relative position of the sleeve to
10 the body. Advantageously the groove extends
11 circumferentially around the sleeve, this enables the
12 tool to be continuously cycled through a number of
13 operating positions.

14
15 Preferably the tool further includes a ball non-return
16 element. Preferably the element is a split ring located
17 in the bore below the sleeve. Advantageously the ring is
18 located at the base of a ramp on an inner surface of the
19 body. Preferably the ramp is arranged such that if a
20 ball pushes against the ring in the first direction, the
21 ring will travel up the ramp and thereby reduce in
22 diameter as edges of the split are forced together. This
23 reduction in diameter will prevent a ball from travelling
24 in a first direction back up through the tool.

25
26 Advantageously the tool includes a ball arrester.
27 Preferably the arrester is located below the ball seat.
28 The inner surface of the sleeve may be shaped to provide
29 the ball arrester. Preferably the ball arrester
30 comprises a plurality of surfaces transversely arranged
31 to the central bore. Preferably the surfaces provide a
32 convoluted path which a ball must take through the
33 sleeve. Preferably the path is sized such that fluid may

1 pass around the ball during its passage. In this way, the
2 momentum of the ball as it passes through the seat is
3 dissipated before the ball reaches any further ball seats
4 in the tool or in the work string to which it is
5 attached. This prevents the ball 'exploding' through
6 restrictions in the bore and allows restrictions, such as
7 further ball seats, to be mounted relatively closely to
8 the ball seat.

9
10 Preferably the tool further comprises a second ball seat.
11 The second ball seat is located below the sleeve and
12 allows the central bore to be blocked in any operating
13 position, if desired.

14
15 The second ball seat may comprise a collet including a
16 plurality of fingers directed in the first direction.
17 Preferably the collet is closed and the fingers are
18 brought together by the action of the sleeve locating
19 between the fingers and the body. In this way, when the
20 sleeve is moved in the reverse direction the passage
21 through the central bore is restricted as the collet
22 closes. A ball is then arrested on the collet. When the
23 sleeve moves in the first direction by a predetermined
24 distance the collet opens and the ball is released to
25 travel through the tool.

26
27 Alternatively the second ball seat may comprise a trapped
28 'C' ring, or split ring. Again movement of the sleeve
29 between the ring and the body will cause the ring to be
30 compressed wherein its diameter reduces. A ball will
31 therefore be prevented from passing through the bore and
32 be impeded at the ring. Movement of the sleeve in the
33 first direction by a predetermined direction will free

1 the ring and, by expansion, the ball can pass through the
2 now increased aperture.

3
4 Advantageously the second ball seat is a shuttle
5 arrangement. The shuttle arrangement comprises a
6 plurality of part cylindrical sleeves. Preferably the
7 sleeves combine to form a complete sleeve which is
8 located in the body. Preferably at least a first part
9 cylindrical sleeve is connected to the sleeve, such that
10 it moves with the sleeve. Preferably at least a second
11 part cylindrical sleeve is attached to the body and is
12 prevented from longitudinal movement in the bore.
13 Preferably the part cylindrical sleeves overlap in the
14 bore at all times, such that movement of the sleeve
15 brings them into sliding engagement. More preferably,
16 when the sleeves are brought together, the internal bore
17 created has a diameter smaller than the diameter of the
18 balls, but that one or more balls can pass between a part
19 cylindrical sleeve and an inner surface of the body.
20 Preferably a free end of each part cylindrical sleeve
21 includes a funnel portion. More preferably the funnel
22 reduces the diameter of the part cylindrical sleeve from
23 that of substantially the body to that of the inner bore.
24 The funnel may be stepped. In this way, only when then
25 the funnels of each part cylindrical sleeve are aligned
26 can balls pass through the second ball seat.

27
28 Preferably the tool is a circulation tool. The
29 functional means may comprise at least one first port
30 arranged substantially transversely to the central bore
31 through the body, and at least one second port arranged
32 transversely to the central bore through the sleeve, such
33 that alignment of the ports causes fluid to be discharged

1 from the central bore and wherein alignment of the ports
2 is controlled by relative movement of the sleeve.

3

4 More preferably there are a plurality of said first and
5 said second ports. Advantageously there are three or more
6 said first and said second ports. Preferably also said
7 first and said second ports are spaced equidistantly
8 around the body and sleeve respectively.

9

10 Preferably also the tool includes ball collecting means.
11 The ball collecting means may be an element located in
12 the casing means to prevent passage of the ball through
13 the tool, but allowing passage of fluid through the tool.

14

15 According to a second aspect of the present invention
16 there is provided a method of circulating fluid in a
17 borehole, the method comprising the steps:

18

- 19 (a) inserting in a work string a tool comprising a
20 tubular body including a plurality of first radial
21 outlet ports in which is located a sleeve including
22 a plurality of second radial outlets;
- 23 (b) running the work string and tool into a borehole,
24 with the sleeve in a first position relative to the
25 body wherein the first and second radial outlets are
26 arranged in a first operating position;
- 27 (c) dropping a ball into the work string such that the
28 ball lands on the sleeve and forces the sleeve into
29 a second position relative to the casing wherein the
30 first and second radial outlets are arranged in an
31 intermediate operating position and fluid flow is
32 restricted by the ball;

1 (d) increasing pressure behind the ball to cause the
2 ball to pass through the sleeve, the releasing
3 pressure allowing the sleeve to move to a third
4 position relative to the body wherein the first and
5 second radial outlets are arranged in a second
6 operating position; and wherein the ports are
7 aligned in either of the operating positions and
8 misaligned in the other operating position.

9
10 In this way, the tool can be run into the borehole with
11 the ports in an open or closed configuration. The
12 intermediate position is a position where the tool is
13 primed between the first and second operating positions.

14

15 Preferably the method further includes the steps of:

16

17 (e) dropping a second ball, substantially similar to the
18 first ball, into the work string such that the
19 second ball lands on the sleeve and forces the
20 sleeve into the second position relative to the body
21 wherein the first and second radial outlets are
22 arranged in the intermediate operating position and
23 fluid flow is restricted by the second ball; and

24 (f) increasing pressure behind the second ball to cause
25 the second ball to pass through the sleeve, the
26 releasing pressure allowing the sleeve to move to
27 the first position relative to the body wherein the
28 first and second radial outlets are arranged in the
29 first operating position.

30

31 With the sleeve and body back in the first position, the
32 steps (c) to (f) can be repeated. In this way the tool
33 can operate in a cyclic manner.

1 Preferably the method includes the step of moving the
2 sleeve against a mechanical bias.

3

4 Preferably the method includes the step of controlling
5 movement of the sleeve relative to the body by use of an
6 index sleeve.

7

8 Preferably the method includes the step of decelerating
9 the ball as it passes from the sleeve to dissipate the
10 pressure.

11

12 Preferably the method includes the step of stopping the
13 ball in a second ball seat after it has passed through
14 the sleeve. Preferably this step further includes the
15 step of preventing fluid flow through the work string
16 while directing it through the radial ports.

17

18 Preferably also the method includes the step of catching
19 the dropped balls in the work string.

20

21 According to a third aspect there is provided a ball
22 arrester for dissipating momentum of a ball after it has
23 passed through a ball seat, the arrester comprising a
24 substantially cylindrical body in which is located a non-
25 linear pathway through which the ball is guided.

26

27 Preferably the pathway comprises a plurality of surfaces
28 transversely arranged to a central bore. Preferably each
29 transverse path has a curved ramp extending therefrom to
30 the next transverse surface. Preferably also each
31 transverse surface extends across a portion of the bore
32 so that the ball can pass between the surfaces.

33 Advantageously adjacent surfaces are off-set so that the

1 ball is forced to run along each surface before
2 travelling to the next surface. Preferably the surfaces
3 provide a convoluted path which a ball must take through
4 the body. Preferably the path is sized such that fluid
5 may pass around the ball during its passage. In this way,
6 the kinetic energy of the ball as it passes through the
7 seat is dissipated before the ball reaches any further
8 ball seats in a tool or in the work string to which it is
9 attached. This prevents a ball 'exploding' through
10 restrictions in the bore and allows restrictions, such as
11 further deformable ball seats, to be mounted relatively
12 closely to the ball seat.

13
14 According to a fourth aspect of the present invention
15 there is provided a ball seat for a downhole tool, the
16 ball seat comprising a plurality of part cylindrical
17 sleeves which can shuttle with respect to each other,
18 longitudinally in the tool, wherein a ball can only pass
19 through the seat when the sleeves are located at their
20 longitudinal extent.

21
22 Preferably the sleeves combine to form a complete sleeve
23 which is located in a cylindrical bore of the tool.
24 Preferably at least a first part cylindrical sleeve is
25 moveable within the tool. Preferably at least a second
26 part cylindrical sleeve is attached to the tool and is
27 prevented from longitudinal movement in the bore.
28 Preferably the part cylindrical sleeves overlap in the
29 bore at all times, such that movement of the first brings
30 them into sliding engagement by a shuttle motion. More
31 preferably, when the sleeves are brought together, the
32 internal bore created has a diameter smaller than the
33 diameter of a ball directed at the seat, but that a ball

1 can pass between a part cylindrical sleeve and an inner
2 surface of the tool. Preferably a free end of each part
3 cylindrical sleeve includes a funnel portion. More
4 preferably the funnel reduces the diameter of the part
5 cylindrical sleeve from that of substantially the body to
6 that of the inner bore. The funnel may be stepped. In
7 this way, only when the funnels of each part cylindrical
8 sleeve are aligned can balls pass through the ball seat.

9
10 According to a fifth aspect of the present invention
11 there is provided an actuation mechanism for a downhole
12 tool, the mechanism comprising a substantially
13 cylindrical body having a central bore running axially
14 therethrough, a sleeve located within the bore, the
15 sleeve including an deformable ball seat,
16 mechanical biasing means located between the sleeve and
17 the body to bias the sleeve in a first direction and a
18 ball, wherein the deformable ball seat releasably retains
19 the ball to prevent fluid flow through the sleeve and
20 cause the sleeve to move in the reverse direction
21 relative to the body and wherein on release of the ball
22 the seat returns to its original dimensions.

23
24 Preferably the mechanical bias is a strong spring. The
25 spring may be helical, conical or the like. A strong
26 spring will prevent the sleeve moving in the reverse
27 direction by fluid flow in the central bore.

28
29 Preferably the deformable ball seat includes a part
30 conical surface having an aperture therethrough.
31 Advantageously the aperture has a diameter less than a
32 diameter of the ball. Preferably the ball seat is made of
33 a flexible or elastic material, so that at a

1 predetermined pressure it flexes to release the ball.
2 Advantageously the ball seat is made of a metal so that
3 the seat is not prone to wear during use. The ball seat
4 may comprise a spring such as a disc spring.

5
6 Optionally the ball seat may be of a layered structure.
7 Preferably the layered structure comprises a plurality of
8 disc springs.

9
10 Preferably the ball is spherical. More preferably the
11 ball is of a non-pliable material and thus cannot deform.
12 Advantageously the ball is made of steel.

13
14 According to a sixth aspect of the present invention
15 there is provided an actuation mechanism for a downhole
16 tool, the mechanism comprising a substantially
17 cylindrical body having a central bore running axially
18 therethrough, a sleeve located within the bore, the
19 sleeve including a helical channel on an inner surface,
20 mechanical biasing means located between the sleeve and
21 the body to bias the sleeve in a first direction and a
22 ball, sized to run in the helical channel in a reverse
23 direction to prevent a majority of fluid flow through the
24 sleeve and cause the sleeve to move in the reverse
25 direction relative to the body.

26
27 Preferably the mechanical bias is a strong spring. The
28 spring may be helical, conical or the like. A strong
29 spring will prevent the sleeve moving in the reverse
30 direction by fluid flow in the central bore.

31
32 Preferably the helical channel has curved walls. This
33 will prevent damage to the ball. Preferably also the ball

1 is sized to provide a restricted fluid by-pass around the
2 ball when in the channel. This ensures a positive
3 pressure is maintained behind the ball and prevents
4 chattering of the ball in the channel.

5
6 The helical channel may be considered as a screw thread.
7 Thus the channel has a left hand thread so that the ball
8 travels in the opposite direction to the rotation of the
9 tool on a work string. Preferably a pitch of the thread
10 is greater than or equal to a diameter of the ball.

11
12 Preferably the ball is spherical. More preferably the
13 ball is of a non-pliable material and thus cannot deform.
14 Advantageously the ball is made of steel.

15
16 Preferably also the sleeve includes a conical surface at
17 an entrance to the channel. This funnels the ball into
18 the channel and ensures it travels into the helical path.

19
20 Embodiments of the present invention will now be
21 described, by way of example only, with reference to the
22 following Figures, of which:

23
24 Figure 1 is a part cross-sectional view of a downhole
25 tool in a first position according to an embodiment of
26 the present invention;

27
28 Figures 2(a)-(c) are schematic illustrations of an index
29 pin positioned in a groove of the tool of Figure 1 for
30 the first, second and third positions respectively;

31
32 Figures 3(a)-(c) are part cross-sectional views of a
33 downhole tool according to a first embodiment of the

1 present invention illustrating a change in operating
2 position from (a) a first operating position to (c) a
3 second operating position;

4

5 Figures 4(a)-(c) are part cross-sectional views of a
6 downhole tool according to a second embodiment of the
7 present invention illustrating a change in operating
8 position from (a) a first operating position to (c) a
9 second operating position;

10

11 Figures 5(a)-(c) are part cross-sectional views of a
12 downhole tool according to a third embodiment of the
13 present invention illustrating a change in operating
14 position from (a) a first operating position to (c) a
15 second operating position;

16

17 Figure 6 is a schematic view of a ball arrester according
18 to an embodiment of the present invention; and

19

20 Figures 7(a)-(c) are part cross-sectional views of a ball
21 seat according to an embodiment of the present invention
22 illustrating a change in operating position from (a) a
23 first operating position to (c) a second operating
24 position.

25

26 Reference is initially made to Figure 1 of the drawings
27 which illustrates a downhole tool, generally indicated by
28 reference numeral 10, in accordance with an embodiment of
29 the present invention. Tool 10 includes a cylindrical
30 body 12 having an upper end 14, a lower end 16 and a
31 cylindrical bore 18 running therethrough. The body 12 has
32 a box section 20 located at the upper end 14 and a pin

1 section 22 located at the lower end 16 for connecting the
2 tool 10 in a work string or drill string (not shown).

3

4 The body 12 further includes five radial ports 24 located
5 equidistantly around the body 12. The ports 24 are
6 perpendicular to the bore 18.

7

8 Within the bore 18 there is located a sleeve 30. Sleeve
9 30 is an annular body which includes five radial ports 32
10 located equidistantly around the sleeve 30. The ports 32
11 are perpendicular to the bore 18. The ports 32 are of a
12 similar size to the ports 24 in the body 12.

13

14 On an outer surface 44 of the sleeve 30 there is located
15 a longitudinal recess 45. Arranged through the body 12 is
16 a pin 47 which locates in the recess 45. Relative
17 longitudinal movement of the pin 47 and recess 45 ensures
18 that the ports 24 in the body will align with the ports
19 32 in the sleeve 30. The sleeve 30 is sealed against body
20 12 by o-rings 31a-d at the ports 24,32.

21

22 A ball seat 34 is located on the sleeve 30 at an upper
23 end 36. The ball seat comprises an aperture or throat 40
24 sized for a ball 68 to rest against and form a seal. The
25 throat 40 also has a diameter less than the diameter of
26 the bore 42 of the sleeve 30. The sleeve includes a
27 conical surface 38 at the upper end 36 to direct the ball
28 68 with minimal turbulence towards the seat 34.

29

30 Located between the outer surface 44 of the sleeve 30 and
31 the inner surface 46 of the body 12 is a space forming a
32 chamber 48. The upper edge of the chamber is formed from
33 a ledge or stop 50 on the outer surface 44 of the sleeve

1 30. The lower edge of the chamber 48 is formed from the
2 ledge 28 of the body 12. A strong spring 52 is positioned
3 within the chamber 48 and compressed to bias against the
4 ledge 50 of the sleeve 30. A similar chamber 49 can be
5 created between the sleeve 30 and the body 12 at other
6 locations in the tool. The restricted passage of fluid
7 into and through these chambers 48, 49 provides a
8 hydraulic damping effect during movement in the tool 10.

9
10 Further an engagement mechanism, generally indicated by
11 reference numeral 56, couples the sleeve 30 to the body
12 12 and controls relative movement there between.
13 Engagement mechanism 56 comprises an index sleeve 58,
14 being located with respect to the sleeve 30, and a
15 matching index pin 60 located through the body 12 towards
16 the sleeve 30. Though only one index pin 60 is
17 illustrated the tool 10 would typically have three or
18 more pins to distribute load over the mechanism 56. Index
19 sleeve 58 includes a profiled groove 62 on its outer
20 surface 57 of the sleeve 30 into which the index pin 60
21 locates.

22

23 Reference is now made to Figure 2 of the drawings which
24 illustrates the groove 62 of the index sleeve 58. The
25 groove 62 extends circumferentially around the sleeve 58
26 and consequently the sleeve 30 in a continuous path. The
27 groove 62 defines a path having a substantially zig-zag
28 profile to provide axial movement of the sleeve 30
29 relative to the body 12. Indeed, spring 52 biases the
30 sleeve 30 against the index pin 60. The path includes an
31 extended longitudinal portion 64 at every second upper
32 apex of the zig-zag. Further a stop 66 is located at the
33 apexes of the zig-zags to encourage the index pin 60 to

1 remain at the apexes and provide a locking function to
2 the tool 10. The stops 66 are in the direction of travel
3 of the pin 60 along the groove 62.

4

5 Further features of the tool 10 will be described
6 hereinafter with reference to later Figures.

7

8 In use, tool 10 is connected to a work string using the
9 box section 20 and the pin section 22. As shown in
10 Figures 1 and 2(a), the spring 52 biases the sleeve 30
11 against the index pin 60 such that the pin 60 is located
12 in the base of longitudinal portion 64 of the groove 62.
13 This is referred to as the first position of the tool 10.
14 In this position, sleeve ports 32 are located above body
15 ports 24, thus preventing fluid flow radially through
16 these ports due to their misalignment. All fluid flow is
17 through bores 18,42 of the tool 10. The tool 10 is then
18 run into a bore hole until it reaches a location where
19 cleaning of the bore hole casing or circulation of the
20 fluid through the tool is required.

21

22 Drop ball 68 is then released through the bore of the
23 work string from a surface. Ball 68 travels by fluid
24 pressure and/or gravity to the ball seat 34 of the sleeve
25 30. The ball 68 is guided by the conical surface 38 to
26 the ball seat 34. When the ball 68 reaches the seat 34
27 it effectively seals the bore 12 and prevents axial fluid
28 flow through the tool 10. Consequently fluid pressure
29 builds up behind the ball 68 and the sleeve 30, including
30 the ball 68, moves against the bias of the spring 52, to
31 an intermediate position. The spring 52 is compressed
32 into a now smaller chamber 48. Fluid has been expelled
33 from the chamber 48. The index pin 60 is now located at

1 the apex 63 of the groove 62 next to the longitudinal
2 portion 64. This is as illustrated in Figure 2(b).
3 Consequently the sleeve ports 32 have crossed the body
4 ports 24 and are now located below them. Fluid flow
5 through the bores 18,42 is prevented by the ball 68.

6
7 As pressure increases on the ball 68 it is released from
8 the ball seat 34 by passing through the throat 40. The
9 ball 68 travels by fluid pressure until it is stopped
10 further through the tool 10 or the work string. On
11 release of the pressure, spring 52 moves the sleeve 30
12 against the index pin 60 such that the sleeve travels to
13 a second position. Fluid has been drawn into the chamber
14 48 and this drawing and expelling of fluid provides a
15 hydraulic damping effect on the impact on the pin 60.
16 Index pin 60 is now located in a base 65 of the groove 62
17 and the ports 24,32 are aligned. This is illustrated in
18 Figure 2(c). In this second position fluid is expelled
19 radially from the tool 10 through the now aligned ports
20 24,32. The tool 10 is locked in this position by virtue
21 of the stop 66 on the groove 62 which prevents movement
22 of the sleeve 30 for small variations in fluid pressure.

23
24 In order to close the ports 24,32, a second ball is
25 dropped from the surface through the work string. The
26 second ball, and indeed any ball subsequent to this, is
27 identical to the first ball 68. The second ball will
28 travel to rest in the ball seat 34. On the build up of
29 fluid pressure behind the ball, sleeve 30 will move
30 downwards against the bias of the spring 52. Consequently
31 the index pin 60 will be relocated into the next apex 63
32 of the groove 62 and thus the tool is returned to the
33 intermediate position. When the ball passes through the

throat 40, the pin 60 and sleeve 30 will move relatively back to the first position and the ball will come to rest by the first ball 68. The index pin 60 has located in the next longitudinal portion 64. Effectively the tool is reset and by dropping further balls the tool 10 can be repeatedly cycled in an open and closed manner as often as desired. The intermediate position can be considered as a primed position.

It will be appreciated that although the description refers to relative positions as being 'above' and 'below', the tool of the present invention can equally well be used in horizontal or inclined boreholes and is not restricted to vertical boreholes.

Reference is now made to Figure 3 of the drawings which illustrates a downhole tool, generally indicated by reference numeral 10, in accordance with a first embodiment of the present invention. Tool 10 has similar features to the tool 10 of Figure 1 and those features have been given the identical reference numerals for ease of interpretation. Tool 10 is a circulation tool operated by the alignment of the radial ports 24,32 of the sleeve 30 and the body 12. Movement is controlled via an engaging mechanism 56, as for Figures 1 and 2.

In this embodiment, located on an inner surface 26 of the body 12 are two opposing ledges 26, 28 used to limit axial movement of the sleeve 30 located within the body 12. The ball seat 34 is located on the sleeve 30 at an upper end 36. The ball seat comprises a conical surface 38 facing the upper end 14 of the tool 10. A throat 40 is provided at a base of the conical surface 38, the throat

1 having a diameter less than the diameter of the bore 42
2 of the sleeve 30.

3
4 Located between the outer surface 44 of the sleeve 30 and
5 the inner surface 46 of the body 12 is a chamber 48. An
6 exhaust port 54 is located through the sleeve 30 at the
7 chamber 48 to allow fluid from the bore 42 to pass into
8 and out of the chamber 48 as the sleeve 30 is moved
9 relative to the body 12.

10
11 Figure 3(a) illustrates the tool 10 when run into a well
12 bore. Figure 3(b) illustrates the tool 10 with a ball 68
13 located in the bore 42. Ball 68 is sized to rest on
14 surface 38 and be of a deformable material e.g. rubber so
15 that under force it changes shape within its own volume
16 to pass through the throat 40. Figure 3(c) of the
17 drawings illustrates the tool 10 with the ball 68 exiting
18 the sleeve 30 into the bore 18. Body 12 includes a pin 70
19 located into the bore 18. Pin 70 is a ball retainer pin
20 which blocks the passage of the ball 68 through the bore
21 18. Ball 68 will come to rest at the pin 70 and therefore
22 be retrievable with the tool 10. Pin 70 does not prevent
23 the flow of fluid through the bore 18 and from the tool
24 10 into the work string below. The pin 70 and the space
25 72 in the bore 18 immediately above it may be considered
26 as a ball catcher.

27
28 In use, tool 10 operates as for the tool described in
29 Figures 1 and 2. When drop ball 68 it travels by fluid
30 pressure and/or gravity to the ball seat 34 of the sleeve
31 30. The ball 68 rests on the conical surface 38 and
32 prevents axial fluid flow through the tool 10.
33 Consequently fluid pressure builds up behind the ball 68

1 and the sleeve 30, including the ball 68, moves against
2 the bias of the spring 52, to the intermediate position.
3 This position is illustrated in Figures 3(b) and 2(b).
4 The spring 52 is compressed into a now smaller chamber
5 48. Fluid has been expelled from the chamber 48 through
6 the exhaust port 54. The index pin 60 is now located at
7 the apex 63 of the groove 62. Consequently the sleeve
8 ports 32 have crossed the body ports 24 and are now
9 located below them. Fluid flow is prevented from passing
10 through the bores 18,42, by the obstruction of the ball
11 68.

12
13 As pressure increases on the ball 68 it is extruded
14 through the throat 40 by deforming. The ball 68 travels
15 by fluid pressure until it is stopped by the pin 70 and
16 is held in the space 72. On release of the pressure,
17 spring 52 moves the sleeve 30 against the index pin 60
18 such that the sleeve travels to the second position. The
19 second position is illustrated in Figures 3(c) and 2(c).
20 Fluid has been drawn into the chamber 48 and this drawing
21 and expelling of fluid provides a hydraulic damping
22 effect on the impact on the pin 60. Index pin 60 is now
23 located in the base 65 of the groove 62 and the ports
24 24,32 are aligned. In this third position fluid is
25 expelled radially from the tool 10 through the now
26 aligned ports 24,32. The tool 10 is locked in this
27 position by virtue of the stop 66 on the groove 62 which
28 prevents movement of the sleeve 30 for small variations
29 in fluid pressure.

30
31 In order to close the ports 24,32, a second ball is
32 dropped from the surface through the work string. The
33 second ball, and indeed any ball subsequent to this, is

1 identical to the first ball 68. The second ball will
2 travel to rest in the ball seat 34. On the build up of
3 fluid pressure behind the ball, sleeve 30 will move
4 downwards against the bias of the spring 52. Consequently
5 the index pin 60 will be relocated into the next apex 63
6 of the groove 62 and thus the tool is returned to the
7 intermediate position. When the ball is extruded through
8 the throat 40, the pin 60 and sleeve 30 will move
9 relatively back to the first position and the ball will
10 come to rest by the first ball 68. Effectively the tool
11 is reset and by dropping further balls the tool 10 can be
12 repeatedly cycled in an open and closed manner as often
13 as desired.

14

15 Reference is now made to Figure 4 of the drawings which
16 illustrates a downhole tool, generally indicated by
17 reference numeral 10, in accordance with a second
18 embodiment of the present invention. Tool 10 includes
19 features in common with the tool illustrated in Figure 3
20 and thus like parts have been given the same reference
21 numerals to aid clarity. Tool 10 is a circulation tool
22 operated by the alignment of the radial ports 24,32 of
23 the sleeve 30 and the body 12. Movement is controlled via
24 an engaging mechanism 56 as for Figures 1 and 2.

25

26 In this second embodiment, ball seat 34 is a deformable
27 ball seat. The seat 34 is located at an upper end 36 of
28 the sleeve 30. A conical surface 38 of the seat 34 faces
29 the upper end 14 of the tool 10. The conical surface 38
30 is part of a disc spring 33 mounted at the upper end 36
31 of the sleeve 30. A perpendicular portion 41 of the
32 spring 33 sits proud of the inner surface 39 of the
33 sleeve 30. The spring 33 is placed in the first direction

1 such that it operates opposite to its typical
2 arrangement. Spring 33 may comprise a stack of disc
3 springs selected to provide a deflection or flex in
4 structure at a desired pressure. Disc springs, and in
5 particular disc springs formed from conical shaped
6 washers (sometimes referred to as Belleville washers) as
7 used here, are well known to those skilled in the art.
8 Such springs are available from, for example, Belleville
9 Springs Ltd, Redditch, United Kingdom. An advantage of
10 these springs is that they return to their original shape
11 following deflection.

12
13 Figure 4(a) illustrates the location of the ball seat 34
14 as the tool is run in a well bore. The tool 10 is in a
15 first operating position with the radial ports 24,32
16 misaligned and the sleeve 30 biased fully upwards by the
17 spring 52. Figure 4(b) illustrates the tool 10 with a
18 ball 68 now located in the bore 42. Ball 68 is located on
19 the deformable ball seat 34 and is sized to block the
20 bore 42. In this way the ball 68 is arrested and pressure
21 builds up behind the ball 68. This pressure moves the
22 ball 68 and sleeve 30 together within the body 12 to the
23 position illustrated. At this point the spring 52 is
24 compressed fully, this being the maximum distance of
25 travel for the sleeve 30. Any additional pressure will
26 now cause the disc spring 33 to flex and release the ball
27 to travel through the sleeve 30 and into the bore 18.

28
29 The ball is of a hard material which is non-pliable.
30 Ideally the ball is made of a metal such as steel.

31
32 Reference is now made to Figure 4(c) which illustrates
33 the tool 10 with the ball 68 now exiting the sleeve 30

1 into the bore 18. Exit of the ball is in an identical
2 manner to that of Figure 3(c).

3

4 In use, tool 10 operates identically to the earlier
5 tools. When ball 68 travels by fluid pressure to the
6 conical surface 38 at the upper end 36 of the sleeve 30.
7 The ball 68 lands on the seat 34 where its progress is
8 arrested. As the ball 68 is now blocking the fluid flow
9 through the bore 42, fluid pressure will build up behind
10 the ball and allow sufficient pressure to build up on the
11 ball 68 and sleeve 30 such that they can move in the
12 direction of applied pressure against the bias of the
13 spring 52. Consequently the sleeve 30 and ball 68 move to
14 an intermediate position. This position is illustrated in
15 Figure 4(b) and 2(b). On increasing fluid pressure on the
16 ball 68, with the sleeve 30 now arrested, pressure is
17 exerted on the ball seat 34. The disc spring 33 will
18 deflect under this increased pressure and ejects the ball
19 68 into the bore 42 below the seat 34. The seat 34 has
20 deformed within its own volume and now returns to its
21 original shape. The ball 68 exits the seat 34 and free
22 falls from this point. On release of the pressure, spring
23 52 moves the sleeve 30 against the index pin 60 such that
24 the sleeve travels to a second position. The second
25 position is illustrated in Figures 4(c) and 2(c). The
26 ports 24,32 are aligned for fluid to be expelled radially
27 from the tool 10.

28

29 In order to close the ports 24,32, a second ball is
30 dropped from the surface through the work string. As with
31 the previous embodiments the tool 10 is reset and can be
32 cycled between the first and second operating position a
33 number of times. The number of times may be dependent on

1 the number of balls which can be caught in the work
2 string.

3

4 Reference is now made to Figure 5 of the drawings which
5 illustrates a downhole tool, generally indicated by
6 reference numeral 10, in accordance with a third
7 embodiment of the present invention. Tool 10 has
8 identical features and operates in an identical manner to
9 the earlier embodiment except that it incorporates an
10 alternative ball seat 34 comprising a helical channel 35.

11

12 At an upper end 36 of the sleeve 30 is located a conical
13 surface 38 facing the upper end 14 of the tool 10.
14 Downwardly extending from the conical surface is a
15 helical channel 35. The channel 35 comprises a continuous
16 spiral groove, having curved walls 41, which takes the
17 path of a screw thread on the inner surface 39 of the
18 sleeve 30. The handedness of the 'screw thread' is left
19 handed.

20

21 Figure 5(b) illustrates the tool 10, now with a ball 68
22 located in the bore 42. Ball 68 is sized to travel along
23 the helical channel 35. Ideally the ball 68 is sized to
24 have a diameter less than or equal to the pitch of the
25 screw thread forming the walls 41 of the channel 35. In
26 this way when the ball 68 travels along the channel 35 a
27 restricted by-pass is created between the edge of the
28 ball 68 and the walls 41 of the channel 35. The ball is
29 of a hard material which is non-pliable. Ideally the ball
30 is made of a metal such as steel.

31

32 In use, tool 10 is connected to a work string and run in
33 a well bore in a first operating position as shown in

1 Figures 2(a) and 5(a), until it reaches a location where
2 cleaning of the bore hole casing or circulation of fluid
3 through the tool is required.

4

5 Drop ball 68 is then released through the bore of the
6 work string from the surface of the well bore. Ball 68
7 travels by fluid pressure and/or gravity to the conical
8 surface 38 at the upper end 36 of the sleeve 30. The ball
9 68 is funnelled into the helical channel 35 where its
10 progress is arrested. As the ball 68 is now blocking the
11 majority of fluid flow through the bore 42, fluid
12 pressure will build up behind the ball and force the ball
13 along the helical channel 35. Due to the size of the ball
14 a small amount of fluid will be allowed to by-pass the
15 ball 68. This restrictive fluid by-pass ensures that a
16 positive pressure is maintained behind the ball 68 so
17 that the ball 68 does not flow towards the upper end 14
18 of the tool 10 also prevents the ball 68 from
19 'chattering' in the channel 35. As the ball 68 makes its
20 way along the channel 35 it acts as a temporary flow
21 restrictor allowing sufficient pressure to build up on
22 the ball 68 and sleeve 30 such that they can move in the
23 direction of applied pressure against the bias of the
24 spring. Consequently the sleeve 30 and ball 68 move to
25 the intermediate position. This position is illustrated
26 in Figure 2(b) and 5(b). Though the ball 68 is at the top
27 of the channel 35 it will be appreciated that this
28 position can be reached with the ball in this position or
29 when the ball 68 has travelled a distance down the
30 channel 35.

31

32 On reaching the base of the channel 35, at the sleeve
33 port 32, the ball 68 exits the channel 35 and free falls

1 from this point. The tool then moves to the second
2 operating position as described with reference to the
3 previous figures.

4
5 As with the earlier embodiments, the tool can be reset
6 and operated in a cyclic manner by the repeated insertion
7 of identical balls 68 into the bore 42.

8
9 Returning to Figure 1, the tool of the present invention
10 can advantageously include a number of further features.

11
12 In the embodiment of Figure 1, there is included a choke
13 ring 51. This lies between the sleeve 30 and the body 12.
14 Alternatively it could form a portion of either the
15 sleeve 30 or the body 12. The ring comprises an elongate,
16 cylindrical portion having at an end a substantially
17 longitudinal portion to provide an 'L' cross section. The
18 ring 51 is arranged close to the sleeve 30 and the body
19 12 to provide a restricted flow path therebetween. The
20 presence and shape of the ring 51 assists in providing a
21 damping action as the sleeve moves in the reverse
22 direction. Fluid, which has to pass the sleeve as it
23 moves downwards is forced to take the restricted flow
24 path in the first direction. This damping helps prevent
25 the mechanical bias e.g. a spring or other parts of the
26 tool 10, from 'bouncing' into a location which could
27 result in the functional means being moved to an unwanted
28 operating position.

29

30 A split ring 81 is also located in the bore 42 of the
31 tool 10. This ring 81 is located below the ports 24, 32.
32 The ring 81 is housed in a recess 83 formed on the inner
33 surface 39 of the sleeve 30. The recess 83 includes a

1 conical portion 85 which provides a ramp whose apex is
2 directed toward the ball seat 34. The ring 81 and recess
3 83 are sized such that the ball 68 can pass easily
4 therethrough as it passes through the sleeve 30 from the
5 upper end 14 to the lower end 16 of the tool 10. However
6 if the ball 68 is, at any time, directed back up the tool
7 10 the ring 81 will prevent its passage. The ball 68 will
8 be influenced by varying fluid pressure and by turbulence
9 within the bore 42 and these may cause the ball 68 to
10 change direction. If the ball 68 changes direction and
11 heads upwards it will contact the ring 81. The ring 81
12 will be moved up the ramp and consequently edges at the
13 split 87 will be brought together as the bore 42 is
14 restricted. The diameter of the ring 81 will decrease
15 sufficiently to a point where it is smaller than the
16 diameter of the ball 68. At this point the ball 68 will
17 stick at the ring 81 and its passage up the bore 42 is
18 prevented. This provides a one-way or non-return feature
19 for the ball 68 within the tool 10.

20

21 A problem encountered in drop ball activated downhole
22 tools is that when a ball is released from a ball seat it
23 can have a significant force associated with it. A ball
24 travelling through a work string at high velocity can
25 have sufficient kinetic energy and resulting momentum to
26 explode through any further restraining apertures in the
27 work string. This prevents certain types of drop-ball
28 activated tools, such as those with expandable or
29 deformable ball seats, being located close to each other
30 on a work string and limits the design of some ball
31 catchers. A ball arrester 90 is located in the tool 10
32 to prevent this. The arrester 90 can be formed as part of
33 the sleeve 30 below the ball seat 34 or can be mounted on

1 the sleeve 30 below the ball seat 34. An embodiment of a
2 ball arrester is shown in Figure 6. The arrester 90 has
3 an upper end 92 and a lower end 94. At the upper end 92
4 there is a recess 96 into which a ball seat 34 may be
5 located.

6
7 As illustrated the arrester may comprise one or more
8 inner surfaces 98 longitudinally arranged between the
9 ends 92,94. In the embodiment shown two surfaces 98a,b
10 are provided. Such an arrangement is easier to machine.
11 On each inner surface 98 there is located a number of
12 transverse ledges 100. Each ledge 100 has a trailing ramp
13 101 towards the lower end 94. The trailing ramp 101 is
14 concave thereby providing a curvature. This curvature
15 guides a ball 68 along the ledge 100. Additionally
16 longitudinally arranged slots or recesses 102 lie
17 perpendicular to the ledges 100 opposing ends of adjacent
18 ledges 100. The ledges 100 and the slots 102 together
19 define a path through the arrester 90. The path is
20 convoluted in that a ball 68 travelling through the
21 arrester 90 is forced to make each transverse crossing
22 before it can fall downwards through the sleeve 30. Each
23 impact of the ball on a ledge 100 slows the ball down and
24 its energy is consequently dissipated through the
25 arrester 90.

26
27 The path through the arrester 90 is sized such that fluid
28 may pass around the ball 68 during its passage. In this
29 way, the pressure on the ball 68 as it passes through the
30 seat is dissipated before the ball reaches any further
31 ball seats in a tool or in the work string to which it is
32 attached. This prevents a ball 'exploding' through
33 restrictions in the bore and allows restrictions, such as

1 further ball seats, to be mounted relatively closely to
2 the ball seat 34.

3

4 Returning again to Figure 1 there is illustrated a second
5 ball seat, generally indicated by reference numeral 110,
6 according to an embodiment of the present invention. The
7 second ball seat 110 is located towards a lower end 16 of
8 the tool 10, below the sleeve 30. In this embodiment the
9 second ball seat 110 is a collet 112, as is known in the
10 art. Collet 112 comprises twelve fingers 114 which are
11 arranged longitudinally in the bore 18. Any number of
12 fingers 114 could be used. The fingers 114 are fixed at a
13 base by being integral with a sleeve 116. The sleeve 116
14 is held to the body 12 so that the collet 112 cannot move
15 longitudinally in the bore 12. The collet 112 is sized so
16 that the fingers 114 rest on the inner surface 46 of the
17 body 12. Each finger 114 has a curved upper edge so that
18 the sleeve 30 can be pushed over the fingers 114. Thus
19 downward movement of the sleeve 30 will cause the sleeve
20 to be pushed between the collet 112 and the body 12. When
21 the sleeve 30 is around the collet 112, the fingers 114
22 are forced radially inwardly and consequently the bore 18
23 is restricted in diameter at this point.

24

25 In use, when the tool 10 is moved to the second operating
26 position, the sleeve 30 will be pushed down against the
27 collet 112 and sit between the collet 112 and the body
28 12. Thus as the ball 68 arrives at the collet 112 the
29 clearance through the bore 12 will have been reduced and
30 there will be insufficient space for the ball 68 to pass
31 there through. As a result the ball 68 will be held in
32 the second ball seat 110. Fluid passing through the bore
33 18 will be substantially prevented from passing the ball

1 seat 110. Axial fluid flow is substantially prevented and
2 this will ensure all fluid flow is through the radial
3 ports 24,32. When a further ball is released into the
4 tool 10, this will cause the sleeve to move back towards
5 the top 14 of the bore 18 and thus the collet 112 is
6 released and the first ball 68 will fall through the tool
7 10. As the sleeve 30 begins to move towards the top 14,
8 the second released ball will fall and hit the first
9 ball. As the sleeve continues to move the second ball
10 seat 110 opens sufficiently to release both balls.

11

12 An alternative embodiment for the second ball seat could
13 be a trapped 'C' ring, or split ring. This would work in
14 a similar way to the non-return split ring 81 presented
15 earlier. The ramp would be replaced by the sleeve 30
16 moving down towards the ring. The end of the sleeve would
17 be shaped to slide in behind the ring. Again movement of
18 the sleeve between the ring and the body will cause the
19 ring to be compressed wherein its diameter reduces. A
20 ball will therefore be prevented from passing through the
21 bore and be stopped at the ring. Movement of the sleeve
22 in the first direction will free the ring and, by
23 expansion, the ball can pass through the now increased
24 aperture.

25

26 A further embodiment of the second ball seat 110 is
27 illustrated in Figure 7. Like parts to those of Figure 1
28 have been given the same reference numeral to aid
29 clarity. Advantageously the second ball seat of this
30 embodiment is a shuttle arrangement, generally indicated
31 by reference numeral 120. The shuttle arrangement 120
32 comprises two semi-cylindrical sleeves 122a,b. The
33 sleeves 122 combine to form a complete sleeve which is

1 located in the body 12. One sleeve 122a is connected to
2 the sleeve 30 and thus moves with the sleeve 30. The
3 other sleeve 122b is fixed to the body 12 towards the
4 lower end 16. The sleeves 122a,b are arranged to overlap
5 in the bore at all times, such that movement of the
6 sleeve brings them into sliding engagement. The sleeves
7 122a,b are sized such that, when the sleeves 122a,b are
8 brought together, the internal bore created has a
9 diameter smaller than the diameter of the balls 68, but
10 that a ball 68 can pass between a sleeve 122a,b and the
11 inner surface 46 of the body 12. A free end 124a,b of
12 each sleeve 122a,b includes a funnel portion 126a,b which
13 presents a ledge or ramp 128a,b towards the free end
14 124a,b. The ledge 128a,b acts as a ball seat if the
15 clearance through the arrangement 120 is insufficient for
16 a ball 68 to pass.

17
18 In use, the tool 10 will be run in the well bore with the
19 sleeves 122a,b furthest from each other as the sleeve 30
20 is towards the top 14 of the tool 10. Funnel portions
21 126a,b overlap and provide a clearance which is greater
22 than the diameter of a ball 68. This provides maximum
23 fluid flow through the tool 10 during run-in. This is
24 illustrated in Figure 7(a). When a ball 68 is located in
25 the ball seat 34, the sleeve 30 is forced downwards and
26 consequently the sleeves 122a,b are shuttled together in
27 to a substantially overlapping position. Clearance
28 between the sleeves 122a,b is now reduced and a ball
29 would be prevented from passing therethrough as it will
30 be held on the lower ledge 128b. This is as illustrated
31 in Figure 7(b). When the ball 68 is released from the
32 ball seat 34 it travels towards the arrangement 120 while
33 the sleeve and consequently the upper sleeve 112a move

1 upwards by a distance determined by the index sleeve 58.
2 They come to rest at a position illustrated in Figure
3 7(c). At this position the ball 68 is caught on the
4 ledge 128 as there is insufficient clearance through the
5 arrangement 120. It will be clear that by dropping a
6 second ball through the tool, the sleeve is moved to the
7 illustrated in Figure 7(a) wherein the funnel portions
8 126a,b meet to provide an aperture through which both
9 balls can exit the tool 10.

10

11 The principal advantage of the present invention is that
12 it provides a downhole tool which can be repeatedly
13 operated by dropping identical balls through the work
14 string. A further advantage is that it provides a
15 circulation tool which can have a number of radial ports
16 to increase the flow area if desired compared with the
17 prior art.

18

19 Further as the actuating mechanism is located above the
20 ports, the ports are opened with no flow going across the
21 seals. This effectively saves the seals from excessive
22 wear. An additional advantage is in the ability of the
23 index sleeve to lock the circulating ports in position
24 when aligned. Yet further the entry and exit of fluid in
25 the chamber for the spring advantageously reduces the
26 impact on the index pin via a hydraulic damping effect.
27 The incorporation on a ball non-return element
28 advantageously prevents balls travelling back through the
29 tool, while a lower ball seat allows selective blocking
30 of the axial bore, for instance, when radially
31 circulating fluid. Yet further the use of a ball arrester
32 allows the ball seats to be mounted close together, thus
33 reducing the length of the tool.

1 Various modifications may be made to the invention herein
2 described without departing from the scope thereof. For
3 example, more index pins could be used to provide
4 increased stability to the tool and distribute the load
5 on the pins. Additional radial ports could be located at
6 longitudinal spacings on the tool to provide radial fluid
7 flow across a larger area when the ports are open. The
8 ports may have varying diameters which may provide a
9 nozzle on the outer surface of the body to increase fluid
10 velocity.

11

1 CLAIMS

2

3 1. A downhole tool for selectively performing a task in
4 a well bore, the tool comprising a substantially
5 cylindrical body having a central bore running
6 axially therethrough, a sleeve located within the
7 bore, the sleeve including a ball seat, a plurality
8 of balls, each ball having substantially similar
9 dimensions and each ball arresting a majority of
10 fluid flow through the bore when located in the ball
11 seat, mechanical biasing means located between the
12 sleeve and the body to bias the sleeve in a first
13 direction, and functional means on the body to
14 perform a task in the well bore, the functional
15 means being operable on relative movement of the
16 sleeve, wherein the functional means has at least a
17 first and a second operating position, each change
18 in position being effected by passing a said ball
19 through the sleeve in a reverse direction, and
20 wherein the said changes form a cyclic pattern such
21 that the functional means can be cycled back to the
22 first operating position.

23

24 2. A downhole tool as claimed in Claim 1 wherein
25 the ball seat releasably retains each ball.

26

27 3. A downhole tool as claimed in Claim 1 or Claim 2
28 wherein the balls are deformable.

29

30 4. A downhole tool as claimed in Claim 1 or Claim 2
31 wherein the ball seat is a deformable ball seat
32 which flexes to release the ball.

33

- 1 5. A downhole tool as claimed in Claim 4 wherein the
2 deformable ball seat comprises a spring such as a
3 disc spring.
4
- 5 6. A downhole tool as claimed in Claim 1 or Claim 2
6 wherein the ball seat comprises a helical channel on
7 an inner surface of the sleeve.
8
- 9 7. A downhole tool as claimed in any one of Claims 4 to
10 6 wherein the balls are of a non-pliable material
11 and thus cannot deform.
12
- 13 8. A downhole tool as claimed in any preceding Claim
14 wherein the mechanical biasing means is a strong
15 spring.
16
- 17 9. A downhole tool as claimed in any preceding Claim
18 wherein a chamber exists between the sleeve and the
19 body which acts as a damper during movement of the
20 sleeve relative to the body.
21
- 22 10. A downhole tool as claimed in any preceding Claim
23 wherein a choke ring is located around the sleeve to
24 provide a damping action by forcing passing fluid to
25 slow down as the sleeve moves relative to the tool
26 body.
27
- 28 11. A downhole tool as claimed in any preceding Claim
29 wherein the tool further comprises engagement means
30 to control relative movement between the sleeve and
31 the body.
32
33

- 1 12. A downhole tool as claimed in any preceding Claim
2 wherein said engagement means comprises at least one
3 index pin located in a profiled groove which extends
4 around the tool.
5
- 6 13. A downhole tool as claimed in any preceding Claim
7 wherein the tool further includes a ball non-return
8 element.
9
- 10 14. A downhole tool as claimed in Claim 13 wherein the
11 element is a split ring located on a ramp within the
12 bore.
13
- 14 15. A downhole tool as claimed in any preceding Claim
15 wherein the tool includes a ball arrester.
16
- 17 16. A downhole tool as claimed in Claim 15 wherein the
18 arrester comprises a plurality of surfaces
19 transversely arranged to the central bore to provide
20 a convoluted path which a ball must take through the
21 sleeve.
22
- 23 17. A downhole tool as claimed in any preceding Claim
24 wherein the tool further comprises a second ball
25 seat, located below the sleeve.
26
- 27 18. A downhole tool as claimed in Claim 17 wherein the
28 second ball seat comprises a collet including a
29 plurality of fingers directed in the first direction
30 operated by the sleeve.
31
- 32 19. A downhole tool as claimed in Claim 17 wherein the
33 second ball seat comprises a trapped 'C' ring.

- 1 20. A downhole tool as claimed in Claim 17 wherein
2 the second ball seat is a shuttle arrangement,
3 wherein the relative position of shuttle elements
4 provide a seat to prevent passage of a ball.
5
- 6 21. A downhole tool as claimed in any preceding Claim
7 wherein the tool is a circulation tool.
8
- 9 22. A downhole tool as claimed in Claim 21 wherein the
10 functional means comprises at least one first port
11 arranged substantially transversely to the central
12 bore through the body, and at least one second port
13 arranged transversely to the central bore through
14 the sleeve, such that alignment of the ports causes
15 fluid to be discharged from the central bore and
16 wherein alignment of the ports is controlled by
17 relative movement of the sleeve.
18
- 19 23. A downhole tool as claimed in any preceding Claim
20 wherein the tool includes ball collecting means.
21
- 22 24. A method of circulating fluid in a borehole, the
23 method comprising the steps:
24
- 25 (a) inserting in a work string a tool comprising a
26 tubular body including a plurality of first
27 radial outlet ports in which is located a
28 sleeve including a plurality of second radial
29 outlets;
30 (b) running the work string and tool into a
31 borehole, with the sleeve in a first position
32 relative to the body wherein the first and

1 second radial outlets are arranged in a first
2 operating position;

3 (c) dropping a ball into the work string such that
4 the ball lands on the sleeve and forces the
5 sleeve into a second position relative to the
6 casing wherein the first and second radial
7 outlets are arranged in an intermediate
8 operating position and fluid flow is restricted
9 by the ball; and

10 (d) increasing pressure behind the ball to cause
11 the ball to pass through the sleeve, the
12 releasing pressure allowing the sleeve to move
13 to a third position relative to the body
14 wherein the first and second radial outlets are
15 arranged in a second operating position; and
16 wherein the ports are aligned in a either of
17 the operating positions and misaligned in the
18 other operating position.

19

20 25. A method as claimed in Claim 24 wherein the method
21 further includes the steps of:

22

23 (e) dropping a second ball, identical to the first
24 ball, into the work string such that the second
25 ball lands on the sleeve and forces the sleeve
26 into the second position relative to the body
27 wherein the first and second radial outlets are
28 arranged in the intermediate operating position
29 and fluid flow is restricted by the second
30 ball; and

31 (f) increasing pressure behind the second ball to
32 cause the second ball to pass through the
33 sleeve, the releasing pressure allowing the

1 sleeve to move to the first position relative
2 to the body wherein the first and second radial
3 outlets are arranged in the first operating
4 position.
5

6 26. A method as claimed in Claim 24 or Claim 25 wherein
7 the method includes the step of moving the sleeve
8 against a mechanical bias.
9

10 27. A method as claimed in any one of Claims 24 to 26
11 wherein the method includes the step of controlling
12 movement of the sleeve relative to the body by use
13 of an index sleeve.
14

15 28. A method as claimed in any one of Claims 24 to 27
16 wherein the method includes the step of decelerating
17 the ball as it passes from the sleeve to dissipate
18 the pressure.
19

20 29. A method as claimed in any one of Claims 24 to 28
21 wherein the method includes the step of stopping the
22 ball in a second ball seat after it has passed
23 through the sleeve.
24

25 30. A method as claimed in Claim 29 wherein the method
26 further includes the step of preventing fluid flow
27 through the work string while directing it through
28 the radial ports.
29

30 31. A method as claimed in any one of Claims 24 to 30
31 wherein the method includes the step of catching the
32 dropped balls in the work string.
33

- 1 32. A ball arrester for dissipating momentum of a ball
2 after it has passed through a ball seat, the
3 arrester comprising a substantially cylindrical body
4 in which is located a non-linear pathway through
5 which the ball is guided.
6
- 7 33. A ball arrester as claimed in Claim 32 wherein the
8 pathway comprises a plurality of surfaces
9 transversely arranged to a central bore.
10
- 11 34. A ball seat for a downhole tool, the ball seat
12 comprising a plurality of part cylindrical sleeves
13 which can shuttle with respect to each other,
14 longitudinally in the tool, wherein a ball can only
15 pass through the seat when the sleeves are located
16 at their longitudinal extent.
17
- 18 35. A ball seat for a downhole tool as claimed in Claim
19 34 wherein at least a first sleeve is stationary
20 while at least a second sleeve moves thereover.
21
- 22 36. An actuation mechanism for a downhole tool, the
23 mechanism comprising a substantially cylindrical
24 body having a central bore running axially
25 therethrough, a sleeve located within the bore, the
26 sleeve including a deformable ball seat,
27 mechanical biasing means located between the sleeve
28 and the body to bias the sleeve in a first direction
29 and a ball, wherein the deformable ball seat
30 releasably retains the ball to prevent fluid flow
31 through the sleeve and cause the sleeve to move in
32 the reverse direction relative to the body and

1 wherein on release of the ball the seat returns to
2 its original dimensions.

3

4 37. An actuation mechanism as claimed in Claim 36
5 wherein the ball seat comprises a spring.

6

7 38. An actuation mechanism as claimed in Claim 37
8 wherein the spring is a plurality of disc springs in
9 a layered structure.

10

11 39. An actuation mechanism for a downhole tool, the
12 mechanism comprising a substantially cylindrical
13 body having a central bore running axially
14 therethrough, a sleeve located within the bore, the
15 sleeve including a helical channel on an inner
16 surface, mechanical biasing means located between
17 the sleeve and the body to bias the sleeve in a
18 first direction and a ball, sized to run in the
19 helical channel in a reverse direction to prevent a
20 majority of fluid flow through the sleeve and cause
21 the sleeve to move in the reverse direction relative
22 to the body.

23

24 40. An actuation mechanism as claimed in Claim 39
25 wherein the mechanical bias is a strong spring.

26

27 41. An actuation mechanism as claimed in Claim 39 or
28 Claim 40 wherein the helical channel has a left hand
29 thread so that a ball travelling through the seat
30 travels in the opposite direction to the rotation of
31 the work string.

32

- 1 42. An actuation mechanism as claimed in Claim 41
- 2 wherein a pitch of the thread is greater than or
- 3 equal to a diameter of the ball intended to pass
- 4 therethrough.